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Roberts Creek Study Forest

Effects of Dispersed Retention Harvesting on Stand Structure and Regeneration in a Coastal Mixed-Conifer Forest: Summary of Year 6 Results

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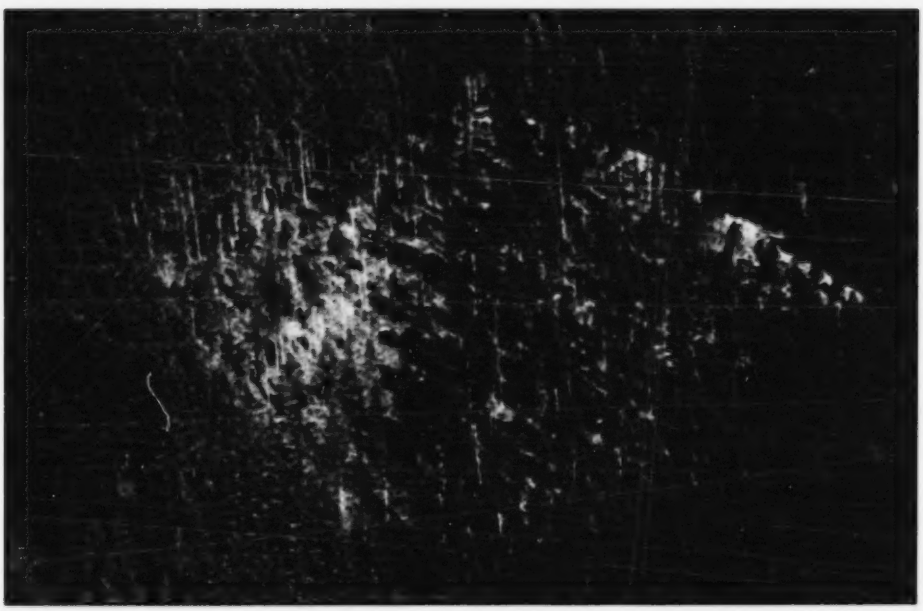

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Cover photo: Aerial view of the demonstration block in the Roberts Creek Study Forest, on the coastal mainland of BC, shortly after the first harvest entry.

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SUMMARY

Throughout the province of British Columbia, social, legislative, and stewardship issues are driving forest managers to evaluate alternatives to clearcutting for harvesting and managing forests. In one example of an alternative to clearcutting, a study of dispersed retention was established in the mature, mixed-conifer forest along the lower slopes of the Sunshine Coast just north of Vancouver, BC.

In the first of two planned harvest entries, dominant Douglas-fir and western redcedar (57 trees/ha) were retained, dispersed throughout a 7.7-ha block. Cable yarding with a Cypress 6280B swing yarder resulted in little damage to the residual stand and caused little disturbance to the soil surface. Subsequent monitoring of windthrow and regeneration (planted and natural) during the six years after harvesting identified issues associated with dispersed retention in these mature stands:

• **Windthrow.** Dispersed trees were prone to blowdown (19.8% of post-harvest stand density), at levels justifying salvage. Western redcedar was more prone to windthrow than Douglas-fir. To manage for windthrow, avoid retaining dispersed trees in wetter soils and beside creeks, and consider crown manipulation (topping and/or pruning) of retained trees during or immediately after harvest.

• **Growth and health of planted regeneration.** Although both western redcedar and Douglas-fir survived beneath the dispersed overstory and reached free-growing height criteria within five years, a negative relationship between Douglas-fir stem diameter growth and overstory density is indicated. Western redcedar growth was less sensitive to overstory density than Douglas-fir. Overstory retention appears to be a factor for explaining the increasing stem gall development on Douglas-fir, which affected 34.5% of saplings by Year 6. The second harvest entry (5 years after the first) caused 8 and 11% of the remaining redcedar and Douglas-fir planted saplings to be significantly damaged or buried.

• **Composition of natural regeneration.** Despite the absence of hemlock in the overstory within the study block, natural regeneration was increasingly dominated by western hemlock. Western redcedar proved to be a poor early natural regenerator, while enhancement of Douglas-fir natural regeneration requires an increase in mineral soil exposure. To achieve the objective of establishing a Douglas-fir-dominated plantation and getting overall regeneration densities within desired levels, stocking control will be required.

KEYWORDS

forestry, forest management, harvest planning, harvesting, silvicultural systems, dispersed retention, shelterwood, windthrow, stand structure, regeneration, seedfall, Douglas-fir, western hemlock, western redcedar, Vancouver Forest Region, British Columbia

ACKNOWLEDGEMENTS

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INTRODUCTION

Among forest managers in British Columbia (BC), interest in alternatives to clearcutting is gaining momentum. This is both a response to society's higher expectations of resource stewardship, and an attempt to provide a greater array of forest-related values. The province's Forest Practices Code (FPC), which was introduced in 1995, requires that non-timber values and the ecological complexity of the forest be addressed in forest management plans; therefore, shelterwood, small patch, and group-selection harvesting systems, as well as single-tree and extended-rotation harvesting systems, are being considered as alternatives to clearcutting.

In the early 1990s, as a means of providing forest managers with more information about alternatives to clearcutting, the South Coast Silviculture Systems Research Co-operative[1] identified priority areas within the Vancouver Forest Region for demonstrating and studying alternative silviculture systems. One area, near Roberts Creek on the Sunshine Coast just north of Vancouver, was considered a suitable study area because the leading species is Douglas-fir, and it presents management issues related to proximity to urban centres and visually sensitive areas. Subsequently the Vancouver Forest Region proposed the Roberts Creek Study Forest (RCSF) be established to demonstrate, evaluate, and develop silvicultural systems that meet a variety of biological, social, and economic objectives.

In 1993, the British Columbia Ministry of Forests (BCMOF) commenced a study of dispersed retention harvesting[2] in the Roberts Creek Study Forest. To help BCMOF personnel and contractors acquire planning and harvesting skills associated with retention of dispersed trees, the Pre-Harvest Silviculture Prescription (PHSP) called for retaining dominant Douglas-fir and western redcedar. The Sunshine Coast Forest District was committed to cable yarding in the area, therefore the PHSP required that yarding corridors be located and that the harvesting equipment be capable of lateral yarding.

Following the first harvest entry in fall 1993, seedfall, regeneration (planted and natural), and overstory stand structure, including windthrow, were monitored annually for five years, and after the second (final) pass in spring 1999. This report summarizes the results of the first six years of monitoring, and highlights the challenges and opportunities of using dispersed tree retention as an alternative to clearcutting.

DESCRIPTION OF THE STUDY BLOCK

The study block, located within the Roberts Creek Study Forest, is approximately 40 km northwest of Vancouver, BC (Figure 1). It lies within the Pacific Ranges Drier Maritime variant of the Coastal Western Hemlock Zone (CWHdm) (Green and Klinka 1994). Climate is characterized by warm, relatively dry summers and moist, mild winters with little snowfall. The 7.7-ha study block is gently sloping (average 11%) with a southwest aspect, and elevation averages 365 m. Prevailing soils on the site are Humo-Ferric podzols, assessed as fresh to slightly dry in moisture and poor in nutrient status with a thin humum layer (<5 cm) (Inselberg 1991). Soils averaged 75 cm in depth before an impermeable layer was reached. The creeks and associated buffers that defined both the west and east edges of the block were classified as S6 creeks, and a smaller stream flowed through the eastern portion of the block (Hudson and D'Anjou 2001). The unmanaged stand, initiated by wildfire in the 19th century and dominated by Douglas-fir (*Pseudotsuga menziesii*), included centuries-old Douglas-fir veterans exceeding 1 m in diameter at breast height (dbh) (Table 1). Shade-tolerant western hemlock (*Tsuga heterophylla*) and western redcedar (*Thuja plicata*) represented the lower crown classes. Salal (*Gaultheria shallon* Pursh) dominated the sparse shrub layer, and *Hylocomium splendens* and *Kindbergia oregana* were the common moss species. Douglas-fir site index is estimated at 32 m (50 years). Past harvesting activities focussed on extraction of cedar snags for shakes and shingles.

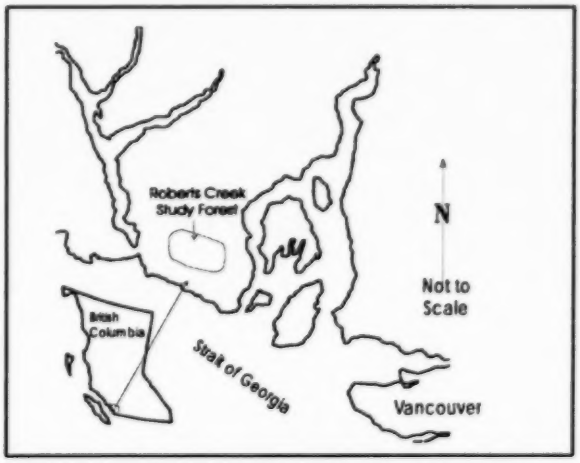


Figure 1. Location of the Roberts Creek Study Forest.

[1] The Co-operative, composed of representatives from academia, government, and other interested organizations, was established in 1990 to assess potential for co-operation in silvicultural systems research, to identify priority biogeoclimatic subzones and potential research sites, and to highlight potential research topics and methodology. The Co-operative is no longer active.

[2] The dispersed overstory cutting pattern prescribed for this study was conceived in 1992 and established in 1993. More recent interest in alternatives to clearcutting has shifted towards prescriptions generically referred to as "variable retention". Variable retention prescriptions typically retain trees in two ways: dispersed, usually at lower densities than tested in this study block; and aggregated into small groups. Crowns of retained trees are sometimes topped or pruned to reduce windthrow potential.

STAND-MANAGEMENT OBJECTIVES

In this study of an alternative to clearcutting, the stand-management objectives listed in the Pre-Harvest Silviculture Prescription included:

1) retaining dispersed overstory Douglas-fir and western redcedar throughout the next rotation for aesthetics, wildlife values, and other resource values,

2) regenerating Douglas-fir and western redcedar for sawlog production, and

3) maintaining water quality by preserving integrity of creeks and other water courses associated with the block.

DESCRIPTION OF THE PRE-HARVEST SILVICULTURE PRESCRIPTION, AND DETAILS OF HARVESTING

A two-pass silvicultural system was developed. The Pre-Harvest Silviculture Prescription prescribed that the first harvest entry should result in retaining 90 stems/ha, excluding area occupied by yarding corridors, composed of dominant Douglas-fir and redcedar. To allow release of the understory Douglas-fir regeneration, a second (final) harvest entry, which would reduce stand density to approximately 30 stems/ha, was not scheduled to take place until at least five years after the first entry. After the second entry, the remaining overstory would be permanently set aside from harvest, or at least until the next rotation, which is estimated will occur in another 90 to 120 years.

First Harvest Entry

The first harvest entry took place between late September and early November 1993. Painting of trees selected for retention preceded the location of yarding corridors. Over 89 stems/ha were marked throughout the block, which was dominated by Douglas-fir by density (85 stems/ha) and volume (326 m^3/ha, or 29% of pre-harvest stand volume) (Figure 2). Western hemlock were not marked for retention, thereby reducing the potential of excessive hemlock regeneration. Additional trees were retained along the east and west edges of the block to protect the integrity of neighbouring creeks.

Table 1. Characteristics of the pre-harvest stand.

Attribute	Douglas-fir	Western redcedar	Western hemlock	Total
Vol. (m^3/ha)	929	45	191	1165
Stems/ha (no.)	394.4	118	158.3	670.7
Avg. dbh (m)	46.5	23.2	32.3	40.2
Basal area (m^2/ha)	67	5	13	85
Avg. height (m)	48.2	34.7	41	44.5

Although site conditions were suitable for ground-based harvesting, cable yarding was specified. Eight yarding corridors were established, with length ranging from 180 to 230 m and inter-corridor distance ranging from 30 to 60 m (Figure 3). A local contractor was awarded harvesting rights through a bidding process. Yarding was conducted with a Cypress 6280B swing yarder rigged with a running skyline. Trees marked for retention and located within corridors were not replaced. Harvesting began in late September 1993 and finished seven weeks later. Harvesting activities were summarized by Hedin (1994).

Post-harvest density was 57 stems/ha (249 m^3/ha) within the central area of the block, but overall density was >68 stems/ha because extra trees were retained beside bordering creeks. Less than 6% of residual trees had basal scars or broken tops caused by harvest activities. Soil disturbance was low (6% mineral soil exposure), and potentially degraded soil conditions (<1%) were restricted to centers of yarding corridor where logs had contacted the ground.

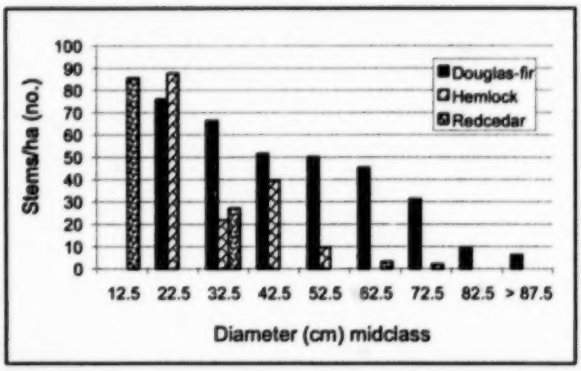
The site was planted in March 1994 with Douglas-fir and western redcedar seedlings (1+1 PBR 415B).

Windthrow (described in following section) was salvaged by helicopter within the first year after harvest.

Second Harvest Entry

The second harvest entry occurred over four days in March 1999. Yarding corridors were located according to the residual stand density, so six of the eight corridors were placed on the eastern end of the block where tree density was greater (Figure 3). A Skyline EX-400 yarder pulled trees to roadside in early March 1999, taking a total of four days to complete. A post-harvest cruise indicated 25 stems/ha remaining, almost entirely Douglas-fir, representing 127 m^3/ha of merchantable volume and 3.5 m^2/ha of basal area.

Figure 2. Distribution of tree diameter (dbh) in the pre-harvest stand, by species.



MEASUREMENTS

Cone crops on dominant Douglas-fir throughout the block were viewed with binoculars prior to harvest, and annually thereafter.

For each tree (minimum 30/y), the cone crop was rated using one of five classes: None, Few, Several, Many, and Loaded. The annual Douglas-fir cone crop was then rated according to the seven-class system in Eremko et al. (1989).

Thirty randomly located circular seed traps (0.25-m^2 collection area) were used to collect seedfall. Material in each seed trap was removed each spring, and seeds were separated and counted by species.

Five seedlings of both Douglas-fir and western redcedar were planted around 35 systematically established reference points throughout the block. Annual measurements on planted regeneration included total stem height, stem diameter (30 cm above ground), and seedling condition. Density and survival of Douglas-fir and redcedar natural regeneration were sampled annually in a 50-m^2 circular area around 21 reference points. Western hemlock density was sampled in 15 to 20 plots in Years 1, 4, and 6. Monitoring of growth and condition of natural regeneration followed the same methods used for monitoring planted regeneration.

Each spring, in a block-wide assessment, all windthrow was located and marked, piece position relative to a reference point was recorded, and dbh and direction of fall were measured.

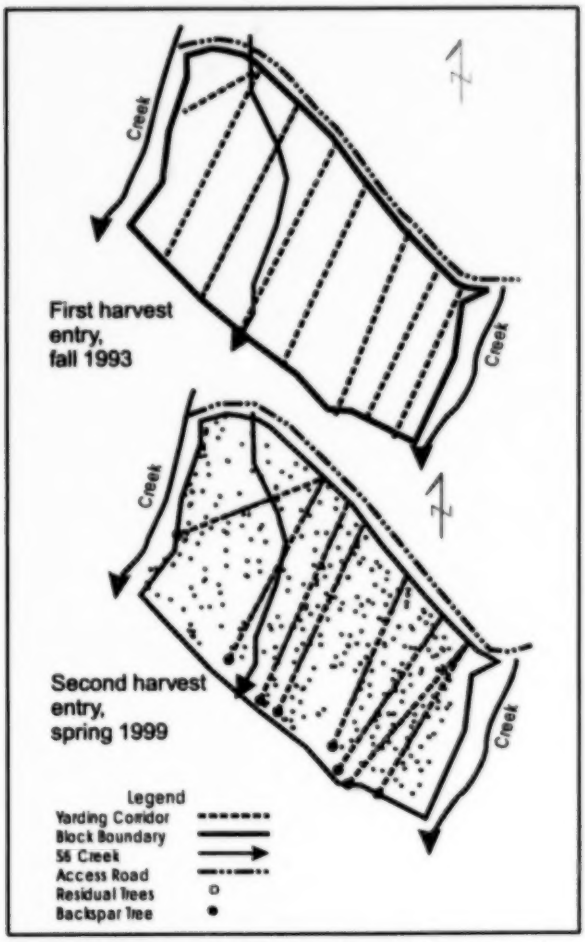


Figure 3. Block layouts for first and second harvest entries. Approximate scale 1:6000.

Windthrow and Current Stand Structure

The first harvest entry was completed in early November 1993; several weeks later a series of winter storms started, with peak gusts from the southwest reaching 55 km/h. Sixty-six trees were uprooted, representing 13% of the residual stand density, and a net volume of 21.7 m^3/ha. Stem breakage occurred on only one tree. Diameters of windthrown trees ranged from 23 to 80 cm, indicating tree size alone did not identify susceptible trees. Trees beside an ephemeral creek blew down in the first storm, presumably due to shallow or unbalanced rooting. Salvage operations, undertaken in 1994 with a Sikorsky 61 helicopter, had little effect on soils or established regeneration. All windthrow that had occurred to date was salvaged.

By Year 5, with 21 additional trees having blown down, windthrow totalled 11.3 trees/ha or 19.8% of the post-harvest stand density (Table 2). Western redcedar comprised about 6% of the post-harvest stand density, but represented 28% of windthrow, indicating it had greater

Table 2. Total windthrow, by species and winter season after harvest.

Winter season after harvest	Douglas-fir (no.)	Western redcedar (no.)	Total (no.)
1st	46	20	66
2nd	1	0	1
3rd	4	1	5
4th	9	3	12
5th	0	0	0
6th	3	0	3
Total trees	63	24	87
Windthrow/ha	8.2	3.1	11.3

susceptibility to windthrow than Douglas-fir. Total residual stand density declined to 39.2 stems/ha by Year 5, representing 192 m^3/ha (>95% Douglas-fir) and basal area of 13.8 m^2/ha. Total windthrow volume exceeded growth of residual trees, resulting in a decline in total stand volume since the first harvest entry.

Douglas-Fir Cone Crops and Conifer Seedfall

Only one heavy Douglas-fir cone crop occurred during the six years of assessment since the first harvest entry (Figure 4), releasing over one million seeds/ha in Year 2, with a germination rate of 54% (Table 3). Subsequent Douglas-fir cone crops declined until Year 5 when no cones were produced. Douglas-fir cone crops within the block were greater than in the surrounding unharvested stands in two of the five years, but similar in the other three years. Western redcedar proved to be a prodigious seed producer despite there being few of these trees in the block. Hemlock seedfall collected within the block indicated seed was originating from trees along the block boundary, at least 100 m from the seed traps.

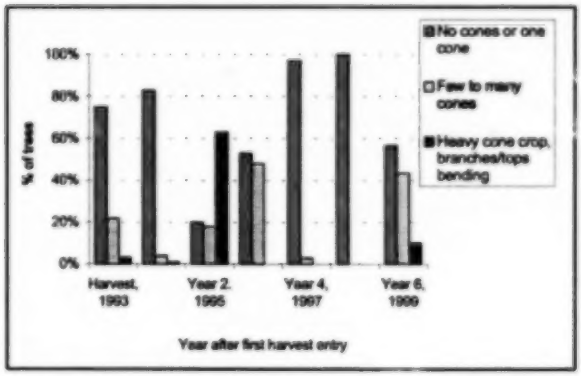


Figure 4. Frequency of Douglas-fir cone crop, by assessment year.

Table 3. Total seedfall, by species and seedfall year.

Seedfall year	Douglas-fir (no. seeds/ha)	Western redcedar (no. seeds/ha)	Western hemlock (no. seeds/ha)
Year 1, 1994	11 000	27 000	16 000
Year 2, 1995	1 312 000	536 000	61 000
Year 3, 1996	874 000	1 760 000	266 000
Year 4, 1997	53 333	213 333	48 000
Year 5, 1998	0	10 667	26 667
Total	2 250 286	3 429 143	417 714

Natural Regeneration

Five conifer species regenerated naturally, including, in decreasing density, western hemlock, Douglas-fir, western redcedar, and single seedlings of sitka spruce *Picea sitchensis* (Bong.) Carr. and western white pine (*Pinus monticola* Dougl. ex D. Don).

Western hemlock density increased in each subsequent measurement period (Figure 5) both in total density and as a percentage of total regeneration density. Douglas-fir natural regeneration established most abundantly in Year 1, but ingress declined in subsequent years (Figure 6). Douglas-fir natural regeneration density, both total and well-spaced density (>2 m inter-tree distance), increased in the first five years but declined by Year 6, and then fell to minimum stocking requirements (500 stems/ha) by

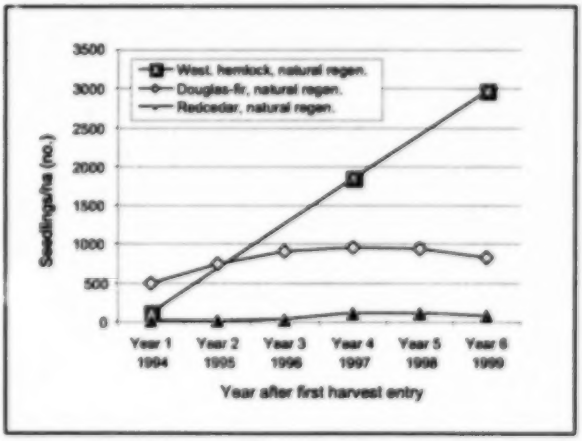


Figure 5. Cumulative natural regeneration density, by species and assessment year.

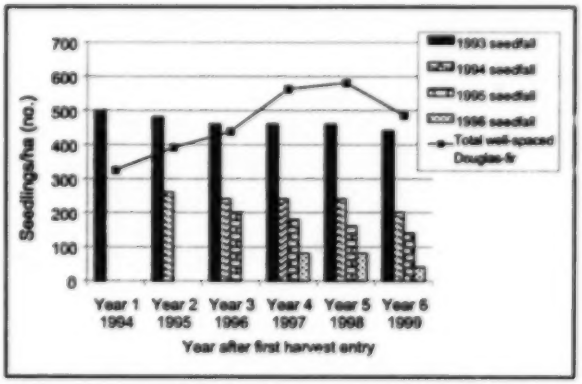


Figure 6. Douglas-fir natural regeneration by seedfall year, assessment year, and cumulative well-spaced regeneration.

Year 5. Douglas-fir germinants survival rates generally exceeded 90%. Douglas-fir germinants establishing in Year 1 reached initial height of planted seedlings in three years but height growth of germinants from subsequent seedfall declined, perhaps due to increasing vegetation competition. Douglas-fir natural regeneration established on a variety of substrates, but favoured rotten wood; rotten wood comprised only 3% of soils substrate, but 37% of germinants established on rotten wood. Mineral soil was also a preferred substrate (16% of germinants establishing on 6% of soil surface). Germination was less successful on undisturbed humus (68% of surface substrate) which was the dominant substrate after harvest. The second harvest entry killed 13% of sampled seedlings.

Planted Regeneration

Year 6 survival of planted Douglas-fir and western redcedar was 81.6% and 77.6% respectively. Mortality of planted seedlings occurred primarily in the first growing season, and during the second harvest entry when 11% of the remaining Douglas-fir and 8% of the redcedar seedlings were cut or buried by slash (Figure 7).

Planted Douglas-fir met free-growing height criterion (3.0 m) in five years and exceeded redcedar height growth during all years except the first year after planting (Figure 8). Redcedar met free-growing height criterion (1.5 m) in four years. Terminal leaders of both species remained above non-crop vegetation, including fireweed, throughout the assessment period. Height (and stem caliper) growth of both species declined in the growing season after the second harvest entry (Year 6). Within-block variability in windthrow distribution created overstory densities ranging from 0 to 105 stems/ha. In Year 5, average stem diameter of Douglas-fir tended to decline as overstory density increased (Figure 9). Redcedar growth was less sensitive to overstory densities, reflecting its more shade-tolerant nature on this site. Stem galls, first observed on Douglas-fir in Year 2 and attributed to *Dioryctria sp.* larva, increased in frequency over time, affecting 34.5% of Douglas-fir saplings by Year 6. Mortality of infected saplings was little different from un-infected saplings.

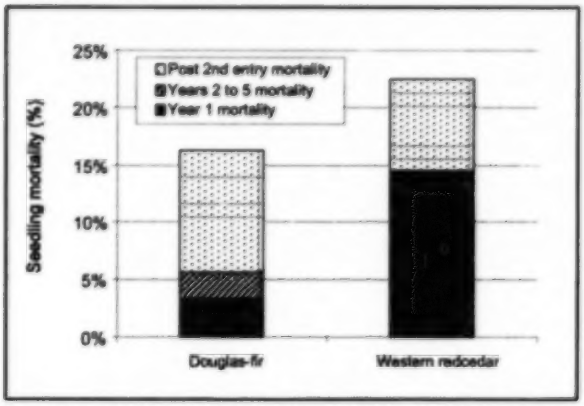


Figure 7. Mortality of planted seedlings, by species and measurement period.

MANAGEMENT ISSUES RELATED TO APPLYING DISPERSED RETENTION

Six years of monitoring windthrow and regeneration in a post-harvest stand of dispersed Douglas-fir and western redcedar has begun to identify short-term and potential longer-term forest-management issues:

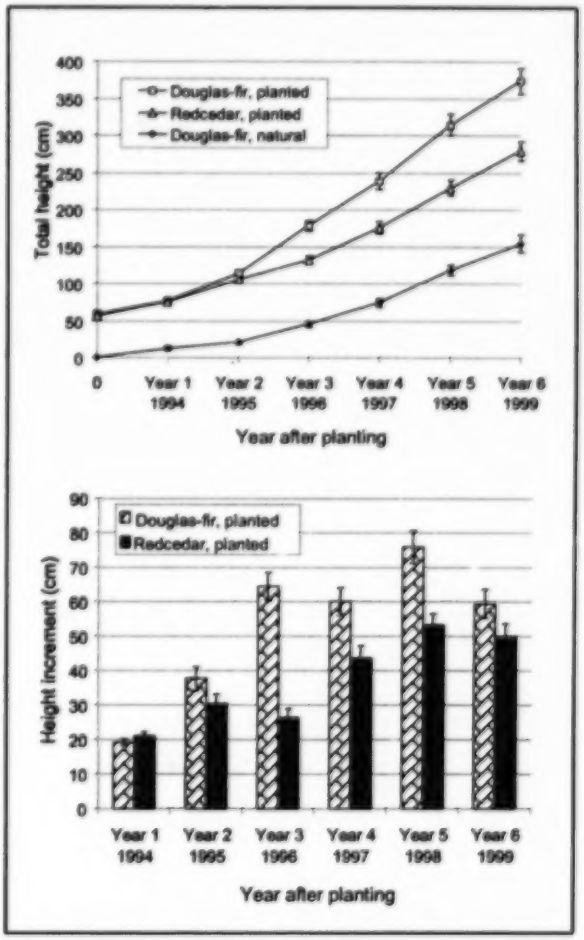


Figure 8. Total height (top) and height growth (bottom) of planted Douglas-fir and western redcedar. Total height graph includes growth of initial natural Douglas-fir regeneration. Error bars indicate 1 s.e. above and below mean.

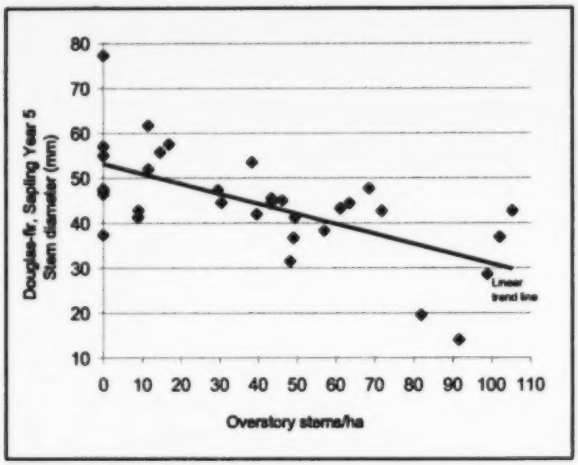


Figure 9. Planted Douglas-fir, Year 5 stem diameter versus overstory density and linear trend line.

Windthrow

A pre-harvest assessment of the study block's windthrow potential (Form FS 712-2[3]), based on site attributes (topographic exposure, soil factors) suggested that a moderate hazard existed; but, using forest stand attributes (including uniform structure, tree height >30 m, and height:diameter ratio >90) would have been more accurate for predicting high hazard.

Windthrow frequency, as a percentage of post-harvest stand density (17%), exceeded that in other provincial studies (Huggard et al. 1999; Coates 1997). Relatively high windthrow frequency was measured in a nearby block where, despite leaving greater overstory density (95 stems/ha), >22% of stems blew over after three years (D'Anjou 2001). Avoiding dispersed tree retention within wetter soils and beside streams and creeks, and/or leaving buffer zones around these areas, may reduce blowdown, while at the same time reducing the potential of introducing sediment into creeks from overturned root wads located beside creeks (Hudson and D'Anjou 2001). Crown treatments, such as topping or branch pruning during or immediately after harvesting, are worthy of consideration. Aggregated retention, around special features that justify preservation, may also reduce windthrow frequency by maintaining mutual support amongst trees through interlocked crowns and roots; it may also simplify prescription development, including tree marking for retention. On the more positive side, windthrow has introduced structural complexity throughout the block, including creation of snags, large upright root wads, and deposited large-diameter woody material; such structures are recognized as habitat for a variety of organisms.

Growth and Health of Planted Regeneration

Both Douglas-fir and western redcedar can survive below dispersed overstory; most seedling mortality was attributed to initial seedling vigour and damage associated with the second harvest entry. Although the annual height growth of planted Douglas-fir (60 cm by Year 3) appeared acceptable considering the block's site index, a negative relationship between overstory density and Douglas-fir stem diameter—the latter being a more sensitive attribute to competition than is height growth—occurred, suggesting that the overstory was suppressing plantation growth.

In nearby blocks, growth suppression beneath a dispersed overstory was confirmed; height growth on three-year-old Douglas-fir and redcedar seedlings beneath dispersed trees (75 stems/ha) was, respectively, 45% and 37% less than on a nearby clearcut (D'Anjou 2001). This supports other research on the BC Coast that shows greater seedling growth with increasing irradiance, and most productive growth under full sunlight conditions (clearcut) (Mailly and Kimmins 1997; Wang et al. 1994). Longer-term growth reductions remain an issue because models suggest that reductions in understory Douglas-fir growth will occur beneath overstory densities as low as 5 trees/ha (Hansen et al. 1995), which is lower than the overstory density remaining in this study. In Year 6 the infection rate of stem gall on planted Douglas-fir reached 34.5% and was attributed to the *Dioryctrai ssp.* larva. Stem gall development has been described on 13% of three-year-old planted Douglas-fir seedlings beneath dispersed overstory in a nearby block (D'Anjou 2001). The absence of galls in a nearby clearcut suggests overstory presence is a factor in gall development. Deformation of the lower stem may affect the longer-term form of affected Douglas-fir stems and is an issue in this block where remaining overstory is permanently set aside from removal.

Composition of Natural Regeneration

The increasing density of western hemlock regeneration since harvest reflects an aggressive regeneration strategy that includes consistent seed crop, widespread seed dispersion, and germination on most substrate types. Enhanced hemlock regeneration beneath a dispersed overstory (75 stems/ha) compared to a nearby clearcut suggests that the dispersed overstory retention enhances hemlock establishment, thereby changing natural regeneration species composition and increasing density. Meeting the objective of establishing a Douglas-fir dominated plantation and meeting target densities beneath a dispersed overstory will require stocking control beyond that expected within a clearcut. In the Roberts Creek Study Forest, enhanced hemlock establishment in the two blocks with dispersed overstory supports the models that

[3] Windthrow Field Cards, Forest Practices Branch, BCMOF (HFP 98/05).

indicate Douglas-fir loses dominance over the more shade-tolerant hemlock under overstory retention levels as low as 5 trees/ha. The result is a decline in wood production (Hansen et al. 1995). Similar trends were revealed in a retrospective study showing relative abundance and density of western hemlock were higher when remnant overstories were higher, and, conversely, Douglas-fir was more prominent when remnant overstory densities were lower (Traut and Muir 2000). To ensure the species becomes established, western redcedar should be planted soon after harvest; this species is initially a relatively poor natural regenerator, and germinants incur a high mortality over a range of seedbed and light conditions (Klinka and Feller 1993). An increase in mineral soil exposure will be required if greater reliance is placed on Douglas-fir natural regeneration for meeting stocking goals.

CONCLUSIONS

To address an increasing interest in using alternatives to clearcutting, in 1993 the BCMOF commenced a study of dispersed retention harvesting in the Roberts Creek Study Forest on the south coast of BC. Seedfall, regeneration, and overstory stand structure were monitored annually; this report summarizes the results for Years 1 to 6.

Dispersed retention of dominant Douglas-fir and western redcedar created forest structures considered desirable for biodiversity, including large-diameter trees, and upright root wads and large-diameter woody debris from subsequent windthrow. However the extent of windthrow, some of which was salvaged, reduced plantation growth, increased Douglas-fir stem gall development, and increased western hemlock regeneration density These are short-term concerns associated with using dispersed tree retention at the initial stand densities prescribed for this study block.

Further monitoring in these and other blocks within the Roberts Creek Study Forest will: quantify the longer-term ability to meet reforestation objectives, assess effects on subsequent windthrow, plus assess opportunities to create structural complexity for biodiversity objectives within a range of cutting patterns.

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